

CLAIMS

What is claimed is:

1. A method of forming a depression in a surface of a layer of photo-resist, comprising:
  - exposing a first portion of the layer of photo-resist with a first dose of radiant energy;
  - exposing a second portion of the layer of photo-resist with a second dose of radiant energy, the second dose being less than the first dose; and
  - baking the layer.
2. The method of Claim 1, wherein the depression forms at the surface of the layer in the second portion of the layer during said baking of the layer.
3. The method of Claim 1, wherein said baking the layer comprises baking the layer at a temperature in a range from 80 to 120 degrees Celsius.
4. The method of Claim 1, wherein said baking the layer occurs after exposing the second portion of the layer of photo-resist with a second dose of radiant energy.
5. The method of Claim 1, wherein said baking the layer comprises:
  - baking the layer after exposing the layer through a first mask and before exposing the layer through a second mask; and
  - subsequently baking the layer after exposing the layer through a second mask.

6. The method of Claim 1 wherein:

said exposing the first portion of the layer of photo-resist with the first dose of radiation comprises exposing the layer through a first mask, the first mask having a transmissive portion corresponding to the first portion of the layer and a non-transmissive portion corresponding to the second portion and a third portion of the layer, and exposing the layer through a second mask, the second mask having a transmissive portion corresponding to the first portion and the second portion and a non-transmissive portion corresponding to the third portion; and

wherein said exposing the second portion of the layer of photo-resist to the second dose comprises exposing the layer through the second mask.

7. The method of Claim 6, wherein said exposing the layer through the first mask comprises exposing the layer with a dose in a range of about 75-300 mJoules/cm<sup>2</sup>.

8. The method of Claim 6, wherein said exposing the layer through the first mask comprises exposing the layer with a dose of about 100 mJoules/cm<sup>2</sup>.

9. The method of Claim 6, wherein said exposing the layer through the second mask comprises exposing the layer with a dose in a range of about 600-2000mJoules/cm<sup>2</sup>.

10. The method of Claim 6, wherein said exposing the layer through the second mask comprises exposing the layer with a dose of about 1000 mJoules/cm<sup>2</sup>.

11. A method of photo-etching a void in a layer of photo-resist, comprising:
  - exposing a first portion of a layer of photo-resist with a first dose of radiant energy;
  - exposing a second portion of the layer of photo-resist with a second dose of radiant energy, the second dose being less than the first dose;
  - leaving a third portion of the layer of photo-resist unexposed to the radiant energy;
  - baking the layer; and
  - developing the layer of photo-resist, thereby forming a void in the layer, the void extending through the layer of photo-resist in the third portion of the layer,
  - wherein the void is within the depression in the surface of the layer in the second portion.
12. The method of Claim 11, wherein the third portion is enclosed within the second portion.
13. The method of Claim 11, wherein the void comprises a lower portion with a substantially circular cross-section, wherein the depression has a substantially circular cross-section, and wherein a circumference of the lower portion of the void lies within a circumference of the depression at the surface.
14. The method of Claim 11, wherein the depression has a generally parabolic shape.
15. The method of Claim 13, wherein the lower portion and the depression are substantially concentric.
16. The method of Claim 11 wherein:

said exposing the first portion of the layer of photo-resist with the first dose of radiation comprises exposing the layer through a first mask, the first mask having a transmissive portion corresponding to the first portion of the layer and a non-transmissive portion corresponding to the second and third portions of the layer, and exposing the layer through a second mask, the second mask having a transmissive portion corresponding to the first portion and the second portion and a non-transmissive portion corresponding to the third portion; and

wherein said exposing the second portion of the layer of photo-resist to the second dose comprises exposing the layer through the second mask.

17. The method of Claim 16, wherein said exposing the layer through the first mask comprises exposing the layer with a dose in a range of about 75-300 mJoules/cm<sup>2</sup>.

18. The method of Claim 16, wherein said exposing the layer through the first mask comprises exposing the layer with a dose of about 100 mJoules/cm<sup>2</sup>.

19. The method of Claim 16, wherein said exposing the layer through the second mask comprises exposing the layer with a dose in a range of about 600-2000mJoules/cm<sup>2</sup>.

20. The method of Claim 16, wherein said exposing the layer through the second mask comprises exposing the layer with a dose of about 1000 mJoules/cm<sup>2</sup>.

21. The method of Claim 16, wherein said exposing the layer through the first mask occurs before exposing the layer through the second mask.

22. The method of Claim 16, wherein said exposing the layer through the second mask occurs before exposing the layer through the first mask.
23. The method of Claim 21, wherein said baking the layer occurs after exposing the layer through the second mask.
24. The method of Claim 22, wherein said baking the layer occurs after exposing the layer through the first mask.
25. The method of Claim 16, wherein said baking the layer occurs after exposing the layer through the first mask and after exposing the layer through the second mask.
26. The method of Claim 16, wherein said baking the layer comprises a first baking of the layer after exposing the layer through the first mask and before exposing the layer through the second mask and a second baking of the layer after exposing the layer through the second mask.
27. The method of Claim 11 wherein said baking the layer comprises baking the layer at a temperature within a range from 80 to 120 degrees Celsius.
28. The method of Claim 11 wherein said baking the layer comprises baking the layer for up to about 5 minutes.
29. The method of Claim 11 wherein:  
exposing the first portion of the layer to a first dose comprises exposing the layer through a mask having a transmissive portion corresponding to the first portion of the layer;

exposing the second portion of the layer comprises exposing the layer through the mask, the mask also having a partially transmissive portion corresponding to the second portion of the layer;

and wherein leaving the third portion of the layer of photo-resist unexposed to the radiant energy comprises exposing the layer through the mask, the mask also having a non-transmissive portion corresponding to the third portion of the layer.

30. The method of Claim 11, wherein the photo-resist is a negative photo-resist.

31. A method for forming a fluid emitter nozzle comprising:  
providing an layer of photo-resist over a surface of a barrier layer;  
exposing a first portion of the photo-resist with a first dose of radiant energy;  
exposing a second portion of the layer of photo-resist with a second dose of radiant energy, the second dose being less than the first dose;  
leaving a nozzle portion of the layer of photo-resist unexposed to the radiant energy;  
baking the layer; and  
developing the layer of photo-resist, thereby forming a nozzle in the nozzle portion and a counter bore at the surface of the layer in the second portion, the second portion having a first diameter at the surface and a second diameter where the nozzle meets the second portion, the first diameter being greater than the second diameter.

32. The method of Claim 31, wherein the nozzle portion is enclosed within the second portion.

33. The method of Claim 31, wherein the nozzle and the second portion have substantially circular cross-sections.

34. The method of Claim 33, wherein the circumference of the lower portion of the void lies within the circumference of the depression at the surface.

35. The method of Claim 34, wherein the nozzle portion and the second portion are substantially concentric.

36. The method of Claim 31 wherein:

    said exposing the first portion of the photo-resist with a first dose of radiant energy comprises exposing the layer through a first mask, the first mask having a transmissive portion corresponding to the first portion and a non-transmissive portion corresponding to the second portion and the nozzle portion, and exposing the layer through a second mask, the second mask having a transmissive portion corresponding to the first portion and the second portion;

    said exposing the second portion of the layer of photo-resist with a second dose of radiant energy comprises the exposing of the layer through the second mask.

37. The method of Claim 36, wherein said exposing the layer through the first mask comprises exposing the layer with a dose in a range of about 75-300 mJoules/cm<sup>2</sup>.

38. The method of Claim 36, wherein said exposing the layer through the first mask comprises exposing the layer with a dose of about 100 mJoules/cm<sup>2</sup>.

39. The method of Claim 36, wherein said exposing the layer through the second mask comprises exposing the layer with a dose in a range of about 600-2000mJoules/cm<sup>2</sup>.

40. The method of Claim 36, wherein said exposing the layer through the second mask comprises exposing the layer with a dose of about 1000 mJoules/cm<sup>2</sup>.

41. The method of Claim 36, wherein said exposing the layer through the first mask occurs before exposing the layer through the second mask.

42. The method of Claim 36, wherein said exposing the layer through the second mask occurs before exposing the layer through the first mask.

43. The method of Claim 41, wherein said baking the layer occurs after exposing the layer through the second mask.

44. The method of Claim 42, wherein said baking the layer occurs after exposing the layer through the first mask.

45. The method of Claim 36, wherein said baking the layer occurs after exposing the layer through the first mask and after exposing the layer through the second mask.

46. The method of Claim 36, wherein said baking the layer comprises a first baking of the layer after exposing the layer through the first mask and before exposing the layer through the second mask and a second baking of the layer after exposing the layer through the second mask.

47. The method of Claim 31, wherein said baking the layer comprises baking the layer at a temperature within a range from 80 to 120 degrees Celsius.

48. The method of Claim 31, wherein said baking the layer comprises baking the layer for up to about five minutes.

49. The method of Claim 31, wherein the first diameter is in a range of about 20um to 40 um.

50. The method of Claim 31, wherein the second diameter is in a range of about 8um-20um.

51. The method of Claim 31, wherein the second portion has a depth in a range of about -0.1um to 3.5 um.

52. The method of Claim 31 wherein:

    said exposing the first portion of the photo-resist with the first dose of radiant energy comprises exposing the layer through a mask, the mask comprising a transmissive portion corresponding to the first portion, a partially transmissive portion corresponding to the second portion and a non-transmissive portion corresponding to the nozzle portion; and

    said exposing the second portion with the second dose of radiant energy comprises the exposing the layer through the mask.

53. A fluid emitter comprising:

    an orifice layer with an upper surface and a lower surface;

    an orifice in the orifice layer from the upper surface to the lower surface;

and

a counter-bore having a generally parabolic shape in the orifice at the upper surface.

54. The fluid emitter of Claim 53, wherein the orifice layer comprises photo-resist, and the orifice and counter-bore are formed by photo-etching.